

# Aggregate Statistics of National Traffic Management Initiatives

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Balancing traffic demand and capacity in the National Airspace System is accomplished through the use of various Traffic Management Initiatives. In this paper, data from the National Traffic Management Log is accessed and examined to provide aggregate statistics on the implementation of Traffic Management Initiatives. Analysis of Monitor Alerts, Reroutes, Ground Delay Programs, Miles-in-Trail Restrictions, Ground Stops, and Airspace Flow Programs is provided. It is shown, for example, that in current-day operations Newark International Airport has the most Ground Delay Programs of any airport, Chicago Center requests the most Miles-In-Trail restrictions, Indianapolis Center implements the most Miles-In-Trail restrictions, and flights into Denver International Airport are the most likely to be rerouted compared to other destinations. Ultimately, the goal of analyzing this database is to improve the performance of traffic flow in the future. To this end, a visualization of the set of initiatives for a given day is developed, which could prove useful in developing decision support tools for national-level Traffic Flow Management.

## I. Introduction

IT is the mission of the FAA's traffic management system to balance traffic demand with system capacity.<sup>1</sup> This balance is achieved through a variety of Traffic Management Initiatives instituted and modified by traffic managers at the regional and national levels. The details of these initiatives are recorded in the National Traffic Management Log. This paper presents aggregate statistics obtained through examination of this log.

The closest related work previously published was completed by Krozel et al.<sup>2</sup> In their paper, the authors offered a detailed look at a range of data from 2000 to 2002. Their sources included the FAA's Aviation System Performance Metrics, Command Center logs, Bureau of Transportation Statistics, Enhanced Traffic Management System Data, and OPSNET data. The Command Center logs are a precursor to the National Traffic Management Log. Krozel et al examined delays, cancellations and traffic volume in addition to Traffic Management Initiatives. For Air Traffic Management research, there is no current literature on operational Traffic Management Initiative statistics. This sort of data is valuable in guiding Air Traffic Management research in many sub-domains.

In this paper, the focus is on data from 2007 through 2009 obtained from the National Traffic Management Log, thus diving more deeply into the statistics involving Traffic Management Initiatives while avoiding topics like volume, cancellations, or delay. Also provided in this paper is a novel method for visualizing what will be characterized as a "Daily Plan" for national Traffic Management. Within this plan, all national-level initiatives are included with overlaid traffic and weather.

The remainder of the paper is organized as follows. In the next section some background information is provided to frame the data analysis that follows. Monitor Alerts are given special attention in Section III. Then Section IV details Miles-in-Trail Restrictions, Reroutes, Ground Delay Programs, Airspace Flow Programs, and Ground Stops. Following the presentation of the data, Section V describes the visualization of a Daily Plan complete with traffic data, weather data, and national-level Traffic Management Initiatives. Finally, concluding remarks and future directions are discussed in Section VI.

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## II. Background

This section is divided into three parts. First, an overview of the Traffic Management system is provided. Next, the variety of Traffic Management Initiatives are described. Finally, the National Traffic Management Log is defined.

### II.A. Traffic Management Overview

Traffic Management is a distributed, hierarchical system within the National Airspace System (NAS). At the top of the hierarchy is the Air Traffic Control System Command Center (ATCSCC), which monitors the NAS, implements national-level Traffic Management Initiatives (TMIs), and provides final approval for all interfacility TMIs, amongst other duties. The NAS over the continental United States is divided into twenty Air Route Traffic Control Centers (or, more simply, “Centers”) each staffed with a Traffic Management Unit (TMU). A TMU has the latitude to implement initiatives within its own Center without necessarily interfacing with the ATCSCC, but any initiative which may involve another Center is likely coordinated through the ATCSCC. Within each Center are a number of Terminal Radar Approach Control (TRACON) facilities which coordinate flights into and out of some number of nearby airports. Each TRACON may have a TMU which interfaces with its encompassing Center’s TMU. An exception to this is the New York TRACON (N90) which communicates directly with the ATCSCC due to its relative location to three Centers. It is through this hierarchy of communication that NAS constraints are identified and potential TMIs are discussed and implemented.

Each Center is divided into several sectors. Each sector is under the direct control of one or two air traffic controllers. Each sector has a Monitor Alert Parameter, which serves as the “capacity” of the sector and is roughly equal to  $5/3$  times the average dwell time of the flight traversing that sector,<sup>3</sup> associated with it. Monitor Alerts are discussed in detail in Section III. In addition to sector capacities, each airport has an arrival and departure rate which must be respected. Other capacities in the system include rates at various fixes or rates into a Flow Constrained Area, but these are usually driven (at least indirectly) by the sector and airport capacities. It is this set of capacities that must be balanced with the demand generated by the flights in the system.

A more comprehensive description of Traffic Management is provided by Sridhar, Grabbe and Mukherjee<sup>4</sup> and the interested reader is directed there for more detail.

### II.B. Traffic Management Initiative Types

The FAA controls demand and capacity imbalances through the use of various Traffic Management Initiatives. As a rule, traffic managers are encouraged to employ the least restrictive initiative available to minimize delays while not overloading available capacity. A brief summary of each of the initiative types summarized from the FAA’s Facility Operation and Administration manual,<sup>3</sup> in order of increasing restrictiveness, is now provided.

1. *Altitude* is used to segregate different flows of traffic either by direction or destination.
2. *LAADR* or Low Altitude Arrival/Departure Routing is a set of routings used in times of severe weather.
3. *MIT* or Miles-in-trail restrictions are used to space flights based on distance in order to control the rates of certain flows into a region or at a fix.
4. *MINIT* or Minutes-in-trail are similar to MIT except that time is used to space the aircraft rather than distance. They are normally used in a non-radar environment.
5. *Fix Balancing* involves assigning a fix other than the one a flight had planned to use. It distributes demand in the arrival and departure phases of flights.
6. *Airborne holding* is planned holding of aircraft when the operating environment allows.

7. *Sequencing Programs* can affect flights from multiple airports and are designed to achieve a specified interval between flights at some fix or to facilitate integration of flights into the en route stream.
8. *Reroutes* assign routing to flights other than their originally filed flight plan.
9. *Ground Delay Programs* involve the assignment of arrival slots to pre-departure flights destined for a predicted over-capacity airport. Each flight affected by the GDP is assigned an Expected Departure Clearance Time (EDCT, pronounced “edict”) which helps ensure that the ability of the destination airport to accept flights will not be overtaxed. Several parameters are used to define a given GDP including scope (which set of flights are affected), program rate, and exempt facilities.
10. *Airspace Flow Programs* are similar to GDPs except instead of arrival slots to an affected airport, entry times to a Flow Constrained Area (FCA).
11. *Ground Stops* are the harshest initiative which dictates that all affected aircraft destined for a severely constrained airport remain on the ground.

## II.C. The National Traffic Management Log

The activities of Traffic Management are communicated through and recorded within the National Traffic Management Log (NTML). All Center TMUs as well as some designated terminals areas are provided access to the NTML. TMUs and members of the ATCSCC use a graphical tool<sup>5</sup> to enter new initiatives or to update previously implemented initiatives. This tool (simply called “NTML”) is part of the suite of tools available through the Traffic Flow Management System (commonly just called “TFMS”). These entries are converted to database entries which are stored for immediate and historical access. It is precisely this set of database entries which were examined for the results presented in subsequent sections.

Before the use of the NTML, each facility may have had its own logging scheme and information regarding the immediate situation was not readily available to all involved parties. With the diverse logging schemes, there was significant redundancy in the information being recorded and communicated. The benefits of moving from the old, loosely controlled logging system to the NTML was studied by Yuditsky and Brickman.<sup>6</sup> They concluded that the potential for human error was reduced by an order of magnitude with NTML and that potential errors did not increase with the complexity of a given scenario. Whereas with the pre-NTML system, there was a linear increase in the number of potential errors as complexity increased. In addition the workload of the participants decreases between five and eight fold with the use of NTML. Finally, they also showed that the median time to complete all of the tested tasks across all scenarios decreased from 7 minutes 31 seconds to 1 minute 51 seconds. Clearly there are large benefits to using a coordinated, unified, electronic system versus the pre-NTML system, especially in the face of complex traffic scenarios.

## III. Monitor Alerts

Monitoring predicted traffic in the NAS allows traffic managers to avoid situations wherein the ability of the sector controller to safely separate flights within his or her sector will not be overly taxed. To accomplish this, a Monitor Alert Parameter is set for each sector. This parameter serves is a “numerical trigger value to provide notification to facility personnel ... that sector efficiency may be degraded during specific periods of time.”<sup>3</sup> In more practical terms, it serves as a maximum capacity for a sector. The average sector flight time ( $\gamma$ ) for aircraft in a sector serves as the parameter determining the baseline MAP value. Table 1 shows the MAP values for sectors as a function of  $\gamma$ . The function is roughly  $5/3 \times \gamma$ . The MAP is dynamic and can be adjusted downward or upward (though not over the baseline) depending on flight conditions, traffic patters, and staffing.

**Table 1. FAA-prescribed Monitor Alert Parameter values from the Facility Operation and Administration manual.**

Average Sector Flight Time ( $\gamma$ ) (min)	3	4	5	6	7	8	9	10	11	12
MAP Value	5	7	8	10	12	13	15	17	18	18

When the number of aircraft is predicted to exceed the MAP, a Monitor Alert is generated. The alert is

“yellow” if any of the flights involved in the prediction have not yet departed. The alert is “red” if all of flights involved in the predicted capacity violation are airborne. These alerts are deemed “false” when the duration of the MAP violation is less than 5 minutes. Monitor Alerts over an hour into the future are often ignored due to the large amount of uncertainty surrounding the positions of the flights involved. All valid red Monitor Alerts are logged, while logging of yellow alerts is optional. The frequency with which yellow Monitor Alerts are logged varies greatly by Center. ZLA is the only Center where the number of yellow Monitor Alerts recorded exceeds the number of red Monitor Alerts recorded as it is the policy of that Center to log each yellow Monitor Alert. This biases the overall distribution of total Monitor Alerts. While ZLC41 shows the highest count for red Monitor Alerts, it is interesting to note that the reports from that sector decreased dramatically between 2007 and 2008. Figure 1 shows the counts for both types of Monitor Alerts for the top 20 sectors reporting red Monitor Alerts. Trends for red Monitor Alerts are further illustrated in Figure 2. The reader will note that the sectors with the highest counts (as noted in the figures) are all in the western United States. Figure 3 provides a geographic visualization of the distribution of total Monitor Alerts reported in NTML.

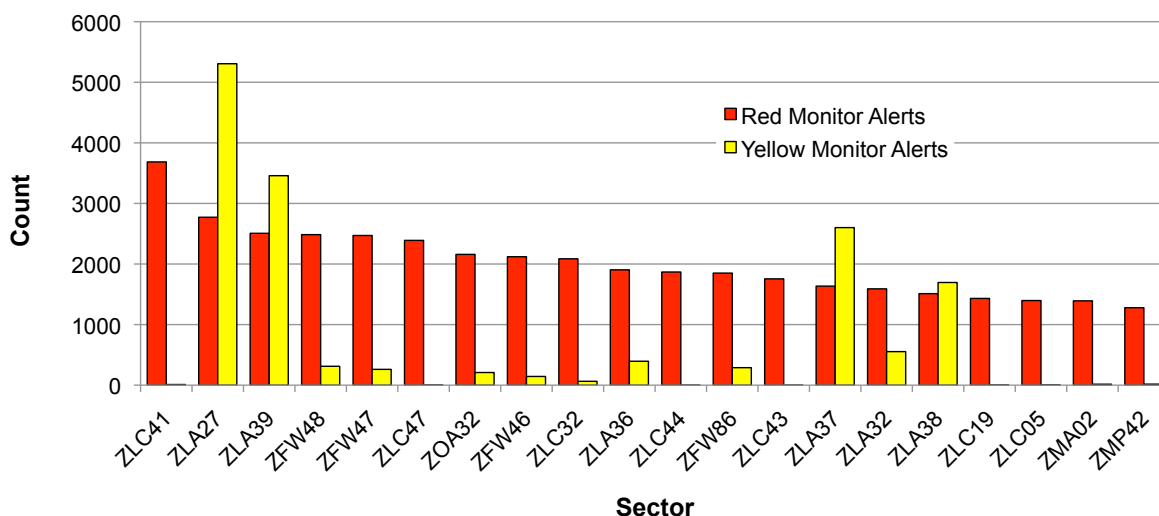


Figure 1. Monitor Alerts for 2005-2009 by top 20 red Monitor Alert-reporting sectors.

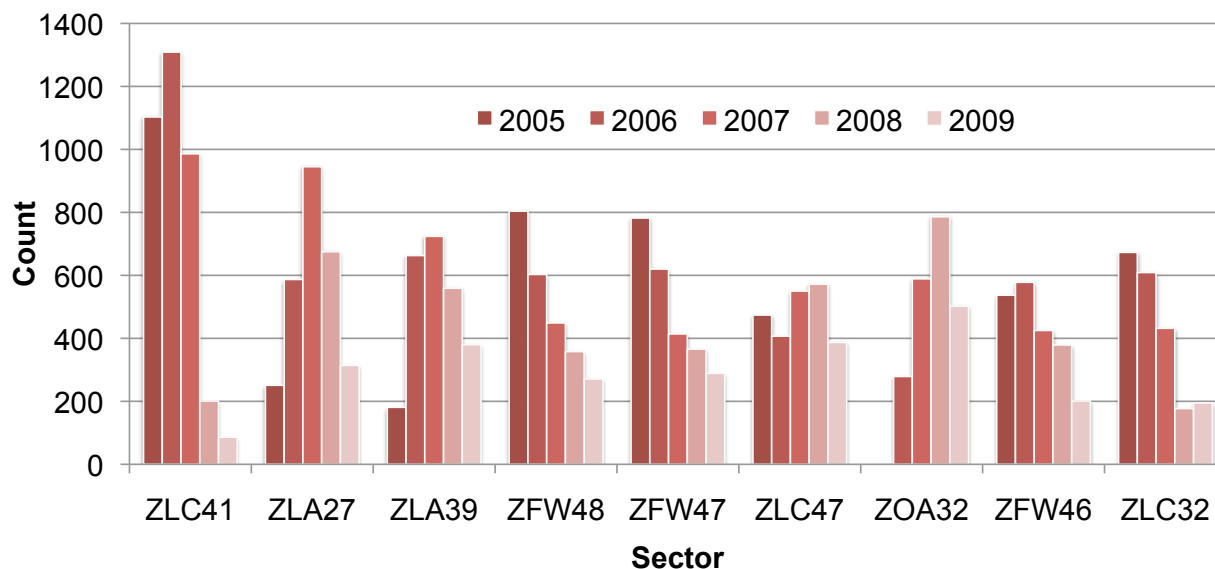
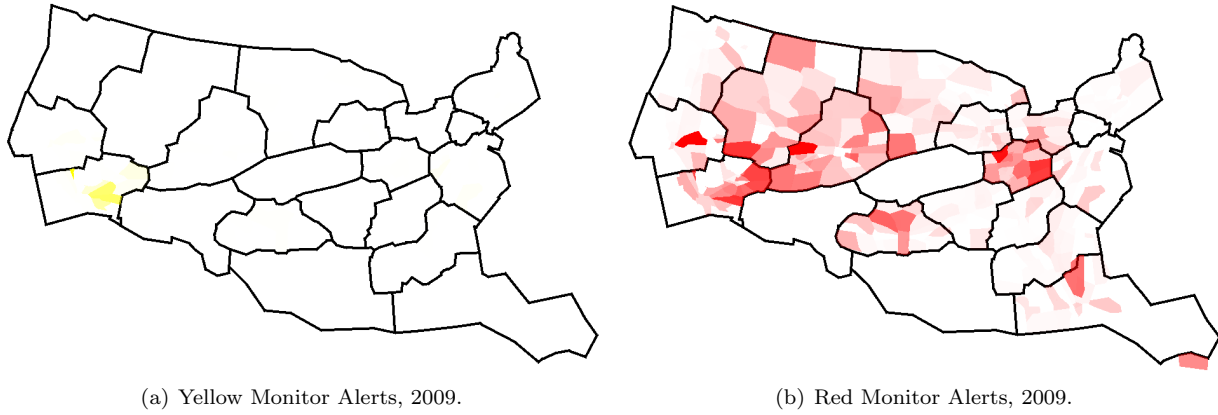


Figure 2. Red Monitor Alerts by sector for 2005-2009 for sectors with at least 2000 reported red Monitor Alerts.



**Figure 3. Comparative distributions of yellow and red Monitor Alerts for 2009.**

The NTML entries for Monitor Alerts contain a text field allowing for description of the action taken along with timing information and the configuration of the sector in question (split or combined). Some examples of the free text entries of the controllers are noted in Table 2. The nature of the free text entries prevents a clean method of automated analysis. Note the term “cap” refers to limiting the altitude of a flight.

**Table 2. Example controller comments noting actions for monitor alerts. Flights anonymized with X’s, sector names omitted.**

Alert type	Comment
Yellow	CAP XXX1321 XXX6505 XXX2818 XXX2319 XXX1105 XXXXX IN LOW ALT
Yellow	CAPPED 3, REROUTED 2
Yellow	REROUTED XXX569/XXX187/XXX429/XXX311 - CAPPED XXX6515/XXX2338 - XXXXXX / XXX2903 /XXX661 FILED O/PMD.
Red	SECTOR RED FOR 1 MINUTE
Red	sup advised he’d cap if needed
Red	LATE ALERT SUP SAYS THEY ARE OK
Red	discussed option with sup to keep 2 sun depts low, as well as two slc dpts landing at sun and boi low. sup advised he’d look at it and call me back if he wanted the slc depts kept out of 41
Yellow	1 non rvsrn, 1 Over with as many as 6 proposals, no tmv initiatives requested
Red	rerouted xxx2112 and xxx753 out of sector

## IV. Traffic Management Initiative Aggregate Statistics

The following subsections will detail various TMIs that are used to keep demand and capacity in balance. Specifically, Miles-in-Trail, Reroutes, Ground Delay Programs, Airspace Flow Programs, and Ground Stops are analyzed and discussed.

### IV.A. Miles-in-Trail Restrictions

Miles-in-Trail restrictions are the most widely used inter-facility TMI. When the flow into a facility (Center or TRACON) needs to be slowed to aid in balancing demand and capacity, a MIT request may be made by one facility to one or more neighboring facilities. Almost all (96%) of such requests are from one facility to one other facility. Figure 4 illustrates the distribution of MIT requests throughout the NAS for a full year (May 2009 through April 2010). The relationship between the Centers in terms of MITs can be implied from the data presented. Chicago Center requests the most MITs (“Frfac” in the NTML and Table 3) of its neighboring Centers (14,628) while Indianapolis Center provides the most MIT restrictions (“Tofac” in NTML) at the behest of its neighbors (14,701). The data also shows that west coast typically has few MITs on average. Note that the data illustrated in Figure 4 does not include MITs requested by TRACONS which can be numerous. For example N90, the New York area TRACON, was the seventh ranking MIT requesting

facility for the dates studied. Table 3 provides the raw numbers of requests from one facility to one other facility.

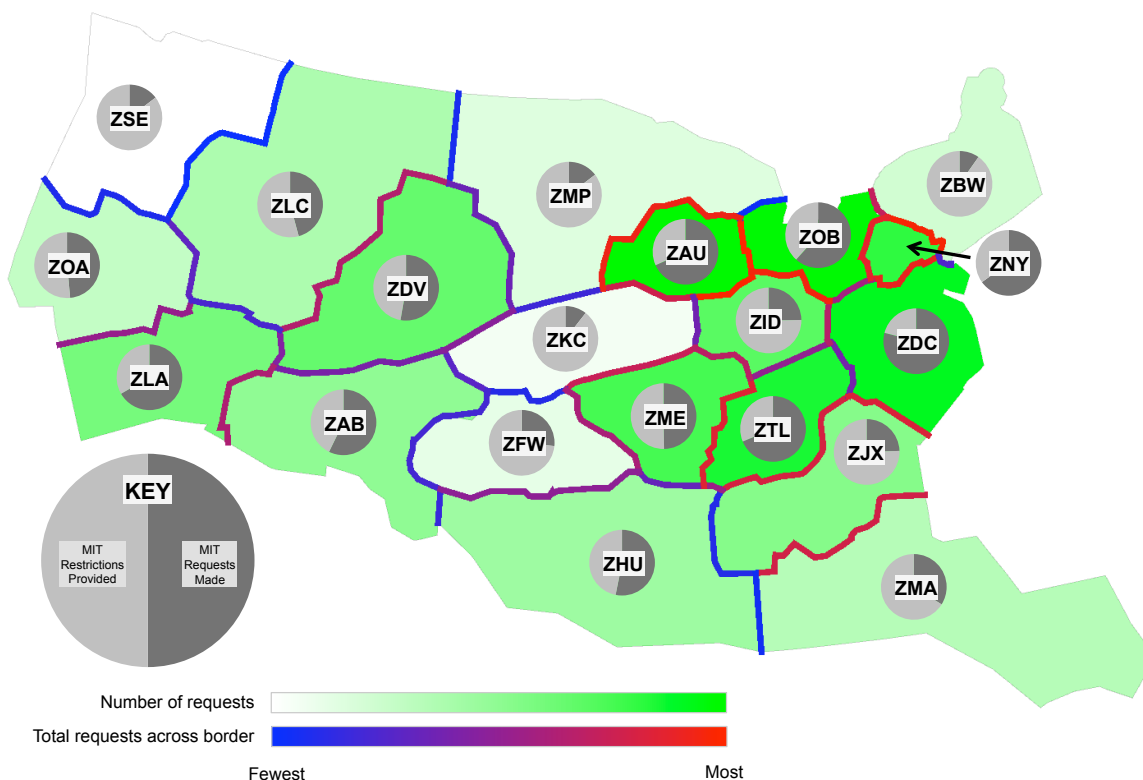


Figure 4. MIT Restrictions for May 2009 - Apr 2010.

Table 3. Counts of MIT requests from one facility to a neighboring facility, May 2009 through April 2010.

		Tofac (Facility providing MIT restriction)																					
		N90	ZAB	ZAU	ZBW	ZDC	ZDV	ZFW	ZHU	ZID	ZJX	ZKC	ZLA	ZLC	ZMA	ZME	ZMP	ZNY	ZOA	ZOB	ZSE	ZTL	Sum
Frfac (Facility requesting MIT)	N90	0	0	0	1742	760	0	0	0	0	0	0	0	0	0	0	0	2247	0	0	0	0	4749
	ZAB	0	0	0	0	0	641	99	24	0	0	370	68	0	0	0	0	0	0	0	0	0	1202
	ZAU	0	0	0	0	0	0	0	0	5366	0	2077	0	0	0	0	3824	0	0	3361	0	0	14,628
	ZBW	518	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	336	0	535	0	0	1401
	ZDC	2	0	0	305	0	0	0	0	1243	2704	0	0	0	1	0	0	3397	0	1045	0	2571	11,268
	ZDV	0	134	0	0	0	0	0	0	0	0	986	146	768	0	0	569	0	0	0	0	0	2603
	ZFW	0	72	0	0	0	0	0	139	0	0	64	0	0	0	505	0	0	0	0	0	0	780
	ZHU	0	84	0	0	0	0	801	0	0	130	0	0	0	57	486	0	0	0	0	0	109	1667
	ZID	0	0	915	0	613	0	0	0	0	0	765	0	0	0	491	0	0	0	747	0	995	4526
	ZJX	0	0	0	0	242	0	0	2	0	0	0	0	0	1630	0	0	0	0	0	0	15	1889
	ZKC	0	2	16	0	0	11	45	0	22	0	0	0	0	0	70	4	0	0	0	0	0	170
	ZLA	0	1004	0	0	0	200	0	0	0	0	0	0	210	0	0	0	0	577	0	0	0	1991
	ZLC	0	0	0	0	0	29	0	0	0	0	0	74	0	0	0	0	0	32	0	0	0	135
	ZMA	0	0	0	0	0	0	0	1	0	639	0	0	0	0	0	0	0	0	0	0	5	645
	ZME	0	0	0	0	0	0	1028	47	1820	0	2070	0	0	0	0	0	0	0	0	0	541	5506
	ZMP	0	0	472	0	0	110	0	0	0	0	18	0	12	0	0	0	0	0	6	0	0	618
	ZNY	2453	0	0	5836	907	0	0	0	0	0	1	0	0	0	5	0	0	0	2729	0	0	11,931
	ZOA	0	0	0	0	0	0	0	0	0	0	0	437	393	0	0	0	0	0	0	84	0	914
ZOB	0	0	5041	1831	448	0	0	0	4949	0	0	0	0	0	0	2	1421	0	0	0	0	13,692	
ZSE	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0	5	
ZTL	0	0	0	0	943	0	0	1384	1301	2772	0	0	0	1	3495	0	0	0	0	0	0	9896	
Sum	2973	1296	6444	9714	3925	991	1973	1597	14,701	6246	6350	725	1386	1694	5047	4399	7401	611	8423	84	4236	90,216	

Another important aspect of MITs is the spacing requested when the MIT is implemented. This value will vary based on many variables including traffic volume, weather, air traffic control staffing, historical MITs, aircraft types, etc. However, on an aggregate level, some trends are noticeable. For the years 2007 through 2009, Figure 5 shows the magnitude of the MIT requested by each Center with at least 20,000 requests over that time period. Notice that ZAU and ZOB have very similar distributions, which is not surprising considering that many MITs requested by these Centers are coupled. ZNY clearly favors 20 miles-in-trail when requesting a restriction (46% of the time), while ZDC requests between 30 and 40 miles-in-trail 42% of the time.

Requested restrictions which are 25 MIT or greater or have a planned duration of over 2 hours must be coordinated with the Command Center. Other restriction requests can be coordinated directly between the requesting (“from”) facility and the providing (“to”) facility.

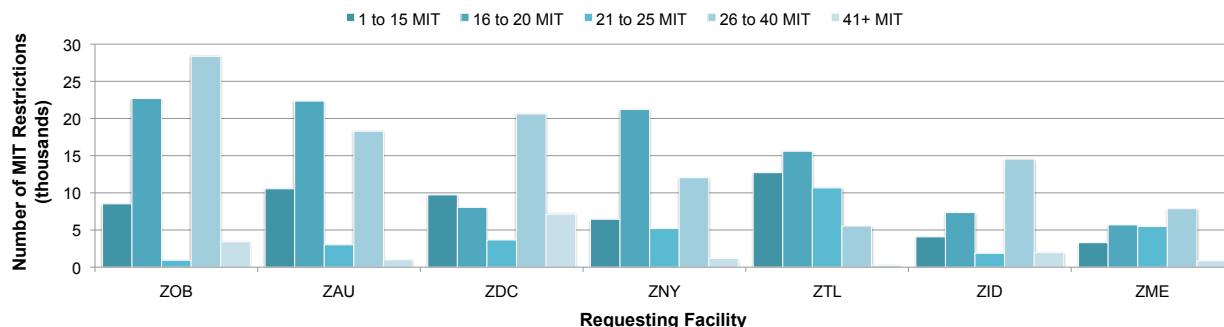


Figure 5. MIT Restriction requests by Centers with at least 20,000 requests between 2007-2009.

## IV.B. Reroutes

When a section of airspace has significantly decreased capacity or is predicted to have excessive occupancy, flights scheduled to traverse that airspace may need to be rerouted. This is especially true when MITs will not be effective enough on their own. Since rerouting will likely need to occur for several aircraft for a given event, a Reroute may be implemented as a TMI to guide the flow of traffic around or to the airspace of concern. Reroutes are issued as an Advisory from the Command Center. As such, the only table in the NTML database which contains data regarding Reroutes is the Advisory table. This differs from other advisories that are issued by the Command Center as GDPs, AFPs, and Ground Stops all have tables containing more detailed information about the TMI than is included in the Advisories table.

Obtaining aggregate statistics regarding Reroutes is further confounded by the shifting nature of the NTML database. The formatting for Reroutes in the Advisories table changed in late 2008. Since analyzing the data from rows conforming to both formats (pre-change and post-change) would be difficult and the current formatting of data in the table is more conducive to data analysis, only data from 2009 will be presented in this paper. A cursory look through the data for 2007 and 2008 seems to confirm that the 2009 is representative (at an aggregate level) of Reroutes issued for all three years.

Commonly used reroutes are defined in the National Playbook published by the FAA. It is defined as follows:

The National Playbook is a traffic management tool developed to give the ATCSCC, other FAA facilities, and customers a common product for various route scenarios. The purpose of the National Playbook is to aid in expediting route coordination during those periods of constraint on the NAS. The National Playbook contains common scenarios that occur during each severe weather season, and each includes the resource or flow impacted, facilities included, and specific routes for each facility involved. These routes may include any combination of the following NAS elements: Navigation Reference System (NRS) waypoints, RNAV waypoints, RNAV fixes, NAVAIDs, DPs, and STARs. The playbooks are validated by the individual facilities involved in that scenario.<sup>3</sup>

In practice, it seems that the National Playbook is used as a starting point for defining reroutes. The vast majority of the time (75.2%) a completely new or modified playbook route is used instead of a published playbook route. Each of these modified or unique Reroutes will have an advisory name that is apparently typed by a traffic manager following some conventions, but not in any strict format. This makes counting similar Reroutes a challenge. To illustrate this point, consider the following Reroute titles, which all describe essentially the same actions on different days:

- FCA001:CHOKE\_POINTS\_EWR\_JFK



- FCA002:CHOKEPOINT\_EWR\_JFK
- FCA001:CHOKEPOINTS\_EWR\_JFK
- FCA002:CHOKEPOINTS\_2\_EWR\_JFK
- FCA002:EWR\_JFK\_CHOKES

Note the preceeding “FCA” designations on each of these items. As will be seen in Section IV.D, there are certain designated “Flow Constrained Areas” in the NAS with given names. The FCAs associated with Reroutes, however, are assigned on a daily basis starting with FCA001 and incrementing as necessary to define the Flow Constrained Areas. Hence, the varying values of FCAs on these Reroutes. This makes the use of the FCA designation unhelpful for any aggregate analysis.

To count and group similar Reroutes (such as those listed above), the following scheme was implemented. Every Reroute name was broken into tokens based on the common underscore delimiter (‘\_’). For example, using the list above, the scheme generated the following tokens: FCA001, CHOKE, POINTS, EWR, JFK, FCA002, CHOKEPOINT, CHOKEPOINTS, 2, CHOKES. After obtaining the list of tokens, they were ranked based on how many Reroutes, which contained that token as a part of the Advisory name, were implemented. That list was then pared to keep only those tokens which referred to an element of the NAS, whether it be an airport, jet route, playbook reroute, or waypoint. This removed many tokens referring to things which would be in common amongst vastly different Reroutes (e.g., CHOKEPOINT, 2, SE, NORTH, ARRIVALS, etc.). Using this ranked list, the entire list of Reroute names was examined. The Reroute was assigned to the first token on the ranked list which it contained. This assignment scheme necessitated a modifying heuristic to the ordering. Any token which contained within it another token on the list (for example “ATLANTIC” contains “ATL”) was moved to a position before the smaller token (for example “ATLANTIC” was moved before “ATL”). If this step was omitted, it would be impossible for the longer token to ever match a given Advisory title. The top 5 tokens (in order) were all airports: DEN, EWR, DFW, JFK, and LGA. Each of the example titles listed above would be assigned to EWR since that is the first token on the list which was contained in the title. Clearly, this favors the tokens which occur higher on the list (e.g., JFK is almost never chosen since EWR is contained in most of the strings which contain JFK), but the results give a good indication of the activity of Reroutes in the NAS.

The resulting counts (accounting for over 80% of all Reroutes in 2009) are presented in Figure 6. A few

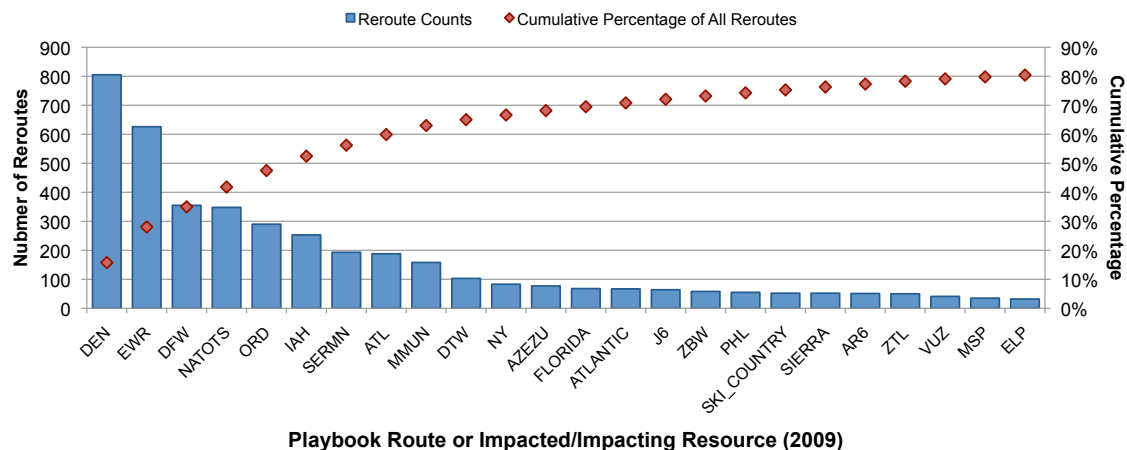


Figure 6. Count of the tokens extracted from playbook reroute names.

notes on the tokens presented in Figure 6 are helpful and now given. “NATOTS” stands for “North Atlantic Organized Track System.” “SERMN” is a compound acronym for “SWAP (Severe Weather Avoidance Plan) Escape Routes for Metro New York” and is the basis for three playbook reroutes. AZEZU (an RNAV waypoint), VUZ, and ELP (Vulcan and El Paso VORTACs, respectively) are waypoints used in defining Reroutes. J6 is a major jet route between the east and west coasts. AR6 is an Atlantic Route. SIERRA and SKI\_COUNTRY are the basis of playbook reroute names (through California and to Denver Center, respectively). The remaining items on the horizontal axis of Figure 6 are airports.



It is curious to note that the flow to Denver International Airport is guided by roughly two Reroutes per day. There is typically one Reroute for prop flights and a separate Reroute for jet flights. No effort was made in this study to determine how similar the various Reroutes are on a day-to-day basis. The flows into the New York-area airports are affected by roughly 2 Reroutes per day as well (note the counts for the token “EWR” and “NY”). If one includes the counts for the SERMN reroutes (routes exiting the New York-area) then this region of airspace clearly accounts for the largest single share of Reroutes in the NAS. Also worth noting is that the NATOTS has essentially daily Reroutes announced which affect flights in both directions across the Atlantic. The “Reroutes” in the NATOTS amount to an announcement of the approved routes for the day.

#### IV.C. Ground Delay Programs

For any given GDP, there may be several entries in the NTML. There are no explicit data that link one GDP entry to another. Thus to count unique GDPs, the NTML field ‘Cumstarttime’ was used. In general, the “cumulative start time” for a GDP across various entries relating to that GDP was constant. Clearly, this method can generate some false counts. For example when the “cumulative start time” changes for a given GDP (this would only occur before the GDP actually begins), this counting method will overcount by one. This miscounting of scenarios happens very seldom and does not taint the aggregate nature of the data being examined. Note that there are other ways to count the number of GDPs in the NTML database. For example, there is an “Advisories” table in the database and GDPs could be extracted from there. The counts from this method and the one documented in this paper agree most of the time and when they do not, the difference is small (generally less than 3%). Counting in the way described above using “cumstarttime” allows for the retrieval of other statistics not easily available through examination of other data tables or sources. Even though counts may vary from one method to another, the aggregate statistics seem to provide the same messages (e.g. EWR has the most GDPs regardless of method of counting).

Figure 7 shows the counts of GDPs at all airports with at least a total of 25 GDPs over the years 2007 through 2009. These data clearly demonstrate that the airports with the most frequent demand-capacity imbalances are the three largest New York-area airports (EWR, LGA, and JFK), San Francisco International (SFO), and Chicago O’Hare (ORD). The reported causes of GDPs are the same as those that are outlined by the FAA for aircraft delays<sup>7</sup> (see Table 4). The major cause of Ground Delay Programs is weather. For comparison, the causes along with subcategories for weather causes are detailed in Figure 8. Details of the 2008 and 2009 weather causes are provided in Table 5. These data are visualized in Figure 9 for three of the most active airports. Altogether, these data illustrate the diverse weather causes for GDPs at each airport. Wind, for example, causes about 50% of the GDPs at EWR, whereas Low Ceilings are the culprit for the vast majority of GDPs at SFO. Meanwhile, ORD shows a distribution of weather causes that corresponds better with the overall national causes of GDPs.

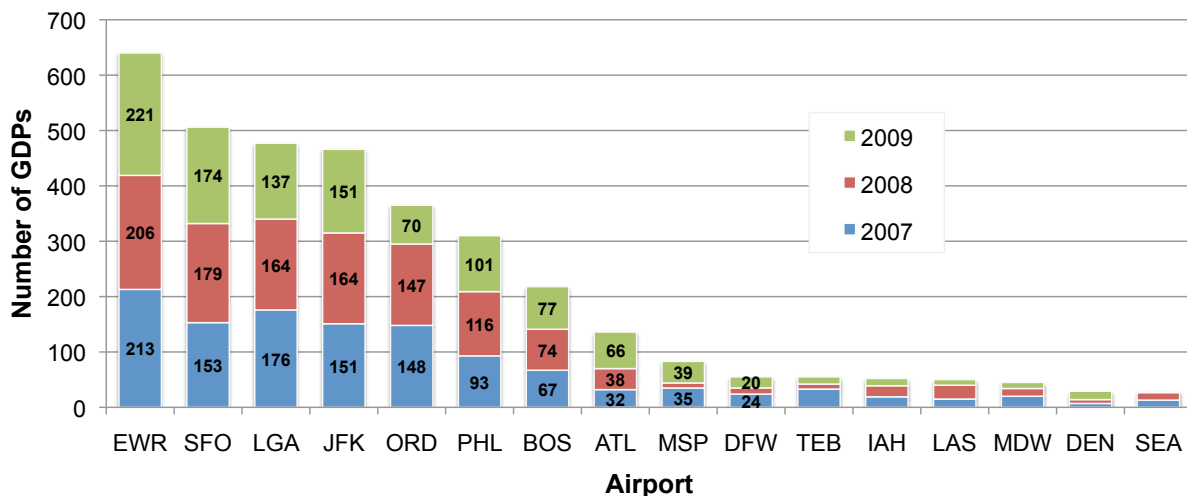


Figure 7. Total GDPs for airports with at least 25 GDPs over the three-year span.

**Table 4. Delay causes as described by FAA.**

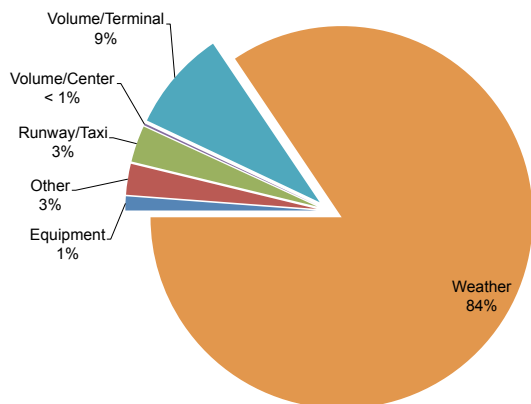
Category	Subcategory
Weather	Fog
	Lightning Strike
	Low ceilings
	Low visibility
	Poor or nil braking action
	Rain
	Runway treatment
	Snow/ice
	Tunderstorms
	Tornado/hurricane
	Wind
Equipment	FAA
	Non-FAA
Runway/taxiway	Noise abatement
	Runway change - operational advantage
	Runway change - operational necessity
	Runway construction
	Runway maintenance
	Runway obstruction
Volume	Disabled aircraft
	Compacted demand
	Mutitaxi
	Volume
Other	
Multiple impacting conditions	

**Table 5. Detailed GDP counts due to weather for top 10 GDP airports for 2008 and 2009.**

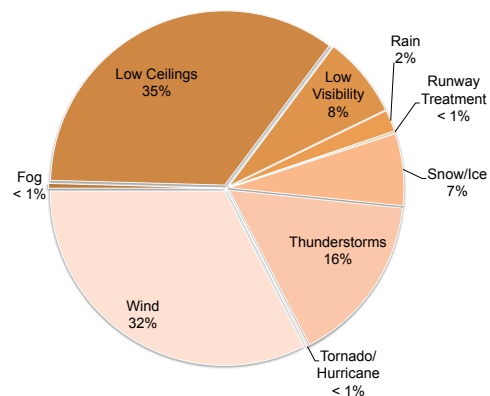
Year	Weather Cause	EWB	SFO	LGA	JFK	ORD	PHL	BOS	ATL	MSP	IAH
2009	Fog	0	3	0	0	1	1	0	0	0	0
	Low Ceilings	43	145	30	29	34	55	37	12	1	2
	Low Visibility	17	12	12	7	14	3	9	2	0	1
	Rain	2	0	2	1	15	2	1	0	0	0
	Runway Treatment	0	0	0	0	1	0	0	0	0	0
	Snow/Ice	4	0	5	7	26	8	3	3	4	0
	Thunderstorms	29	0	26	28	23	22	14	19	2	10
	Tornado/Hurricane	0	0	0	0	0	0	0	0	0	1
	Wind	103	16	80	56	49	19	11	3	2	6
2008	Fog	0	2	1	0	0	1	1	0	0	0
	Low Ceilings	57	145	38	36	25	55	42	35	8	0
	Low Visibility	12	2	8	5	10	2	6	7	0	0
	Rain	7	2	0	1	2	0	1	1	0	0
	Runway Treatment	0	0	0	0	0	0	0	0	0	0
	Snow/Ice	9	0	5	3	14	6	6	1	6	1
	Thunderstorms	22	0	23	18	13	17	8	21	0	10
	Tornado/Hurricane	0	0	0	0	0	0	0	0	0	0
	Wind	115	17	64	77	6	19	10	5	3	0

When a GDP is initially issued, there may be a need to modify the GDP before its conclusion. These modifications may include changes to the acceptance rate, the expected end time of the program, the delay calculations of affected flights, or one of several other parameters. Figure 10 illustrates the rate at which these modifications were made for some of the more affected airports in 2009 for the top ten GDP airports for that year. These modifications may be interpreted as reactions to uncertain conditions. In this light, SFO (about one modification per GDP) seems to have better predictability than EWR (about two modifications per GDP). Further analysis would be necessary to make any definitive conclusions on this matter.

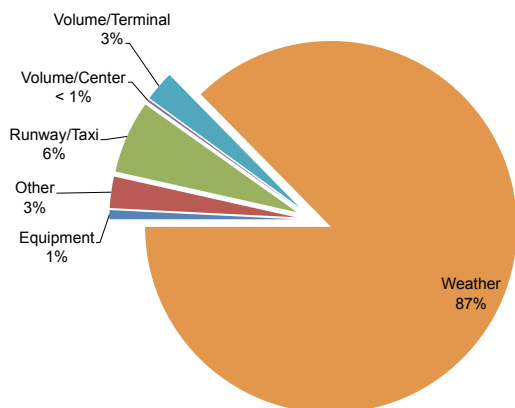
For most GDPs a cancellation message is issued signifying the end of the GDP. Some GDPs (less than 10%



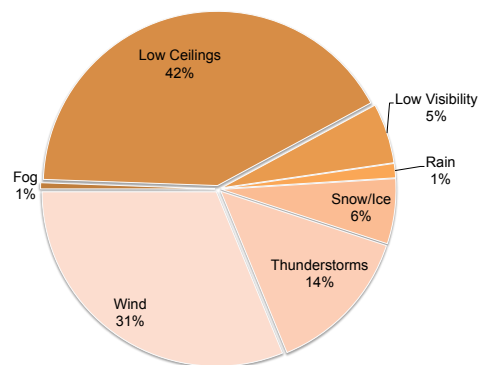
(a) Causes of Ground Delay Programs for 2008.



(b) Specific weather causes for 2008.

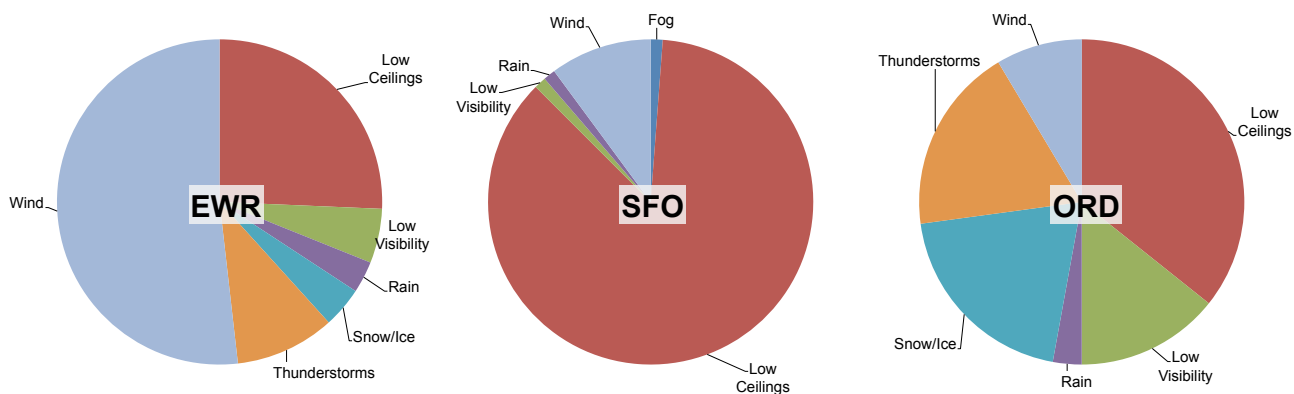


(c) Causes of Ground Delay Programs for 2009.



(d) Specific weather causes for 2009.

**Figure 8. Ground Delay Programs for 2008 and 2009 by cause and by specific weather cause.**



**Figure 9. Weather causes of Ground Delay Programs for three heavily impacted airports in 2009.**

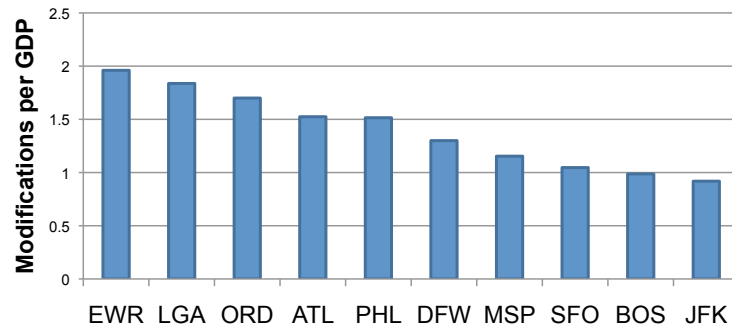


Figure 10. The average number of modifications to GDPs during 2009.

in the data investigated for this study) end without the issuance of a cancellation message. By using the initial GDP message and the cancellation message, a calculation of the length of the GDP is easily made. For a GDP which ends without a cancellation message, the last message associated with that GDP (either an 'INITIATE' or 'MODIFY' message) is used for the end time by using the 'Cumendtime' (cumulative end time) column for that message as the end time for the GDP. The results of these calculations for GDPs issued for 2007, 2008, and two months of 2009 are presented in Figure 11.

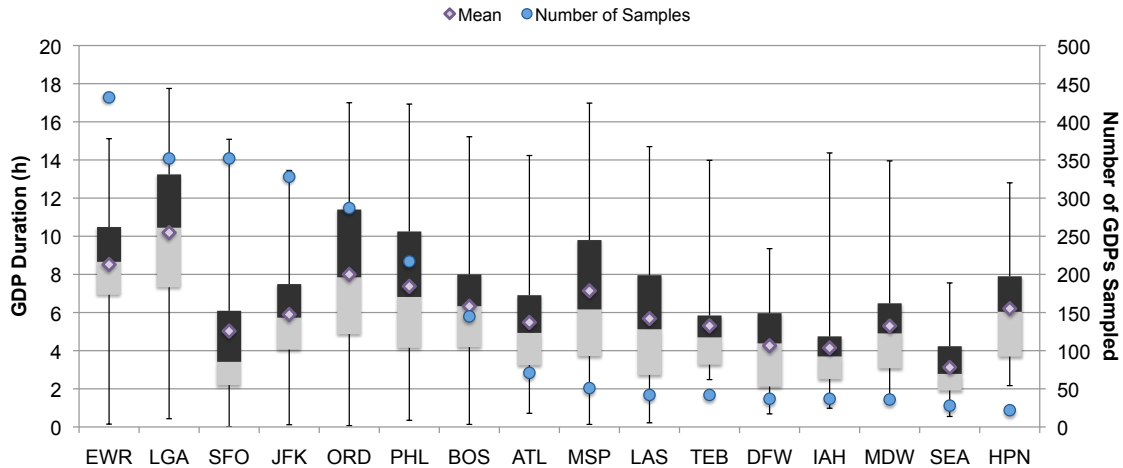


Figure 11. Duration of GDPs for some of the more heavily affected airports over a 26-month period.

#### IV.D. Airspace Flow Programs

An Airspace Flow Program (AFP) is an initiative with parameters similar to that of a GDP. They are so similar, in fact, that the data for AFPs is stored in the same table of the NTML as GDPs. The major difference between the two types of initiatives is that AFPs control the flow of aircraft into or through a volume of airspace versus controlling the flow of aircraft to a particular airport. The volume of airspace used is often one-dimensional (i.e. a border). All of these volumes are referred to as Flow Constrained Areas (FCA) and the most commonly used FCAs have designated names (e.g. FCAA01, FCASD1). Figure 12 provides counts of AFPs in 2008 and 2009 by cause.

The two most commonly used FCAs for implementing AFPs are FCASD1 and FCAMU1. These two FCAs are actually over Mexican airspace, one over the west coast over Baja California and the other on the east coast over the Yucatan peninsula. Discounting those two, the two most commonly used FCAs for implementing AFPs are shown in Figure 13 by the images the FAA provides when issuing AFPs.

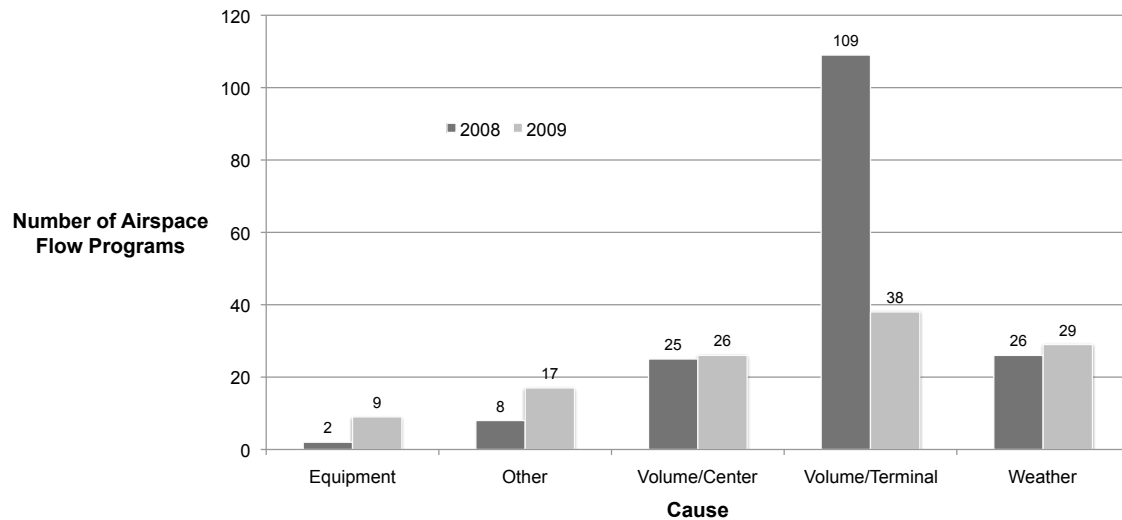


Figure 12. Counting Airspace Flow Programs by cause and year.

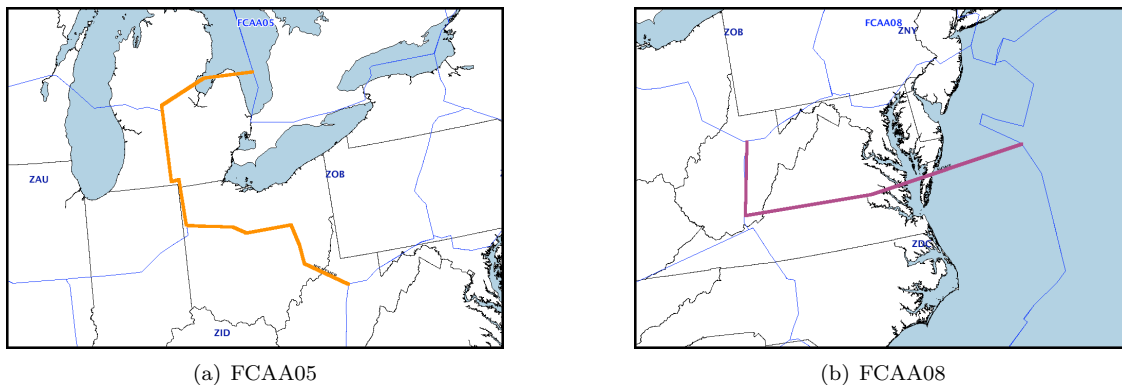


Figure 13. Location of the two most commonly used domestic Flow Constrained Areas for implementing AFPs.

#### IV.E. Ground Stops

A Ground Stop (GS) at an airport halts all affected flights from departing for that airport. It is, in essence, a GDP with an acceptance rate of zero. A GS is often issued in conjunction with one or more GDPs at an airport. For example, a GDP may be initially issued and then if the conditions worsen, a GS may be issued for some time during the GDP. Likewise, a GS may be eased into a GDP as demand-capacity imbalances improve. Figure 14 shows the GS counts by year for all airports with at least 70 GSs over the course of those 3 years.

An interesting comparison is that of the count of GDPs versus GSs at each airport. Figure 15 shows the relative usage over the years 2007-2009 of the two TMI strategies at the airports which issued the most GDPs. Note that some airports almost exclusively use Ground Stops (e.g., CLT, IAD, DEN) while several issue almost equal numbers of each TMI (e.g., EWR, LGA, ORD, PHL). For the latter set of airports, it should be noted that the roughly equivalent counts often corresponds to the scenarios described above, i.e. a GDP and a GS are often issued consecutively (in one order or the other) to handle a demand-capacity imbalance at an airport. SFO is the lone airport which clearly favors the use of the GDP over GSs. There is not a GS “season.” There is a nearly flat distribution of GS over months of the year for years 2007-2009.

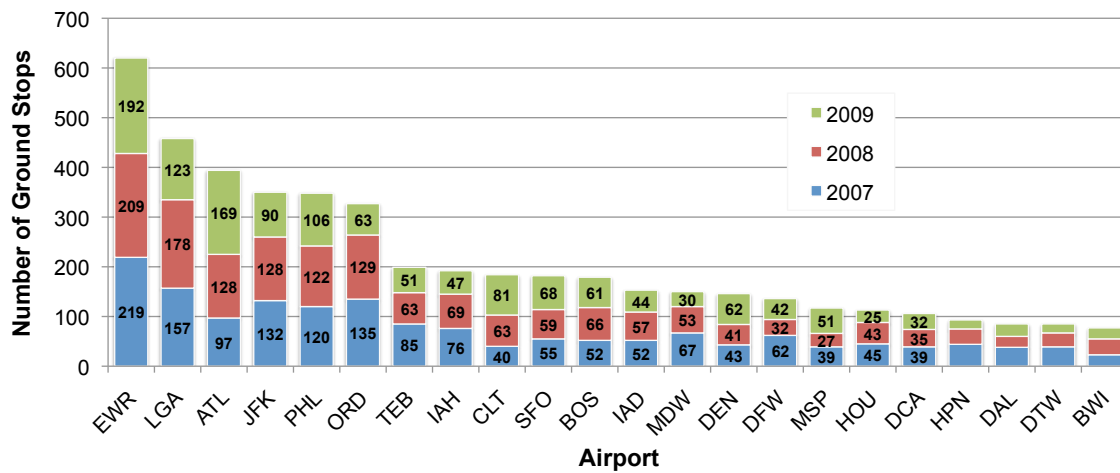


Figure 14. Total Ground Stops for airports with at least 70 Ground Stops over the three-year span..

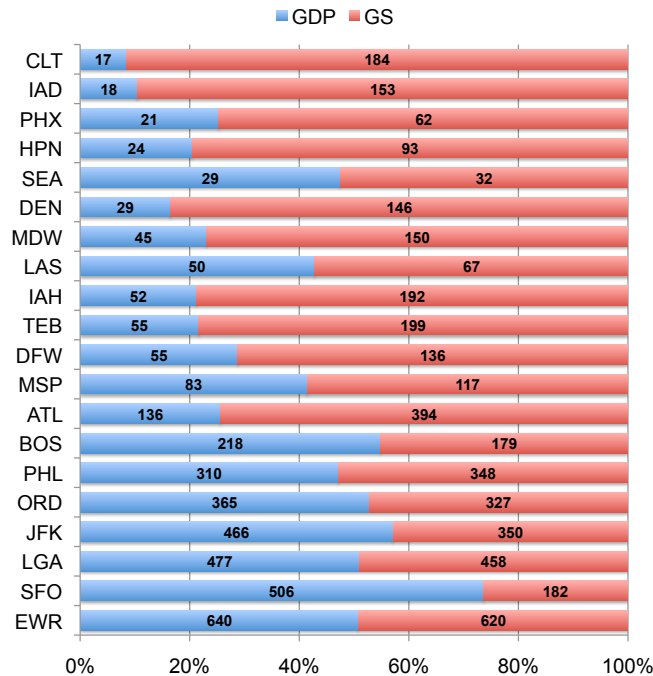


Figure 15. Comparison of relative usage of GDPs versus GSs by airport for 2007 through 2009.

## V. TMI Viewer

Ultimately, the goal of analysis of the NTML data is to improve performance of traffic flow in the future. Visualization of the TMIs enacted on a given day could prove a useful step in this direction. To this particular end, the implementation described below takes as input various TMI data files, traffic data, and weather data and produces a temporal view of the traffic activity on a given day. The output is termed the “TMI Viewer.” The TMI data is pulled from the NTML database, filtered, and then re-formatted. Traffic data is given in the form of historical Aircraft Situation Display to Industry (ASDI)<sup>8</sup> data. The weather data is historical Corridor Integrated Weather System data.<sup>9</sup> The Future ATM Concepts Evaluation Tool (FACET)<sup>10</sup> supplies the visualization capabilities through a Java Application Programming Interface. The complete flow of the data is provided in Figure 16. Figure 17 then shows an example frame from the TMI Viewer.

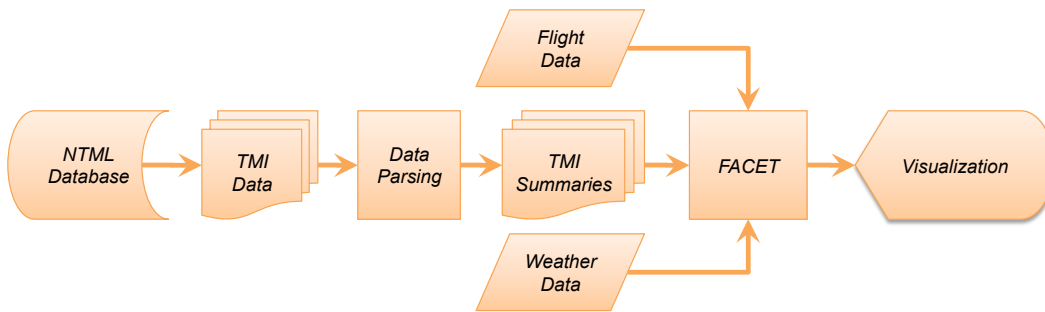


Figure 16. The flow of data and tools used to generate a visualization of the Daily Plan.

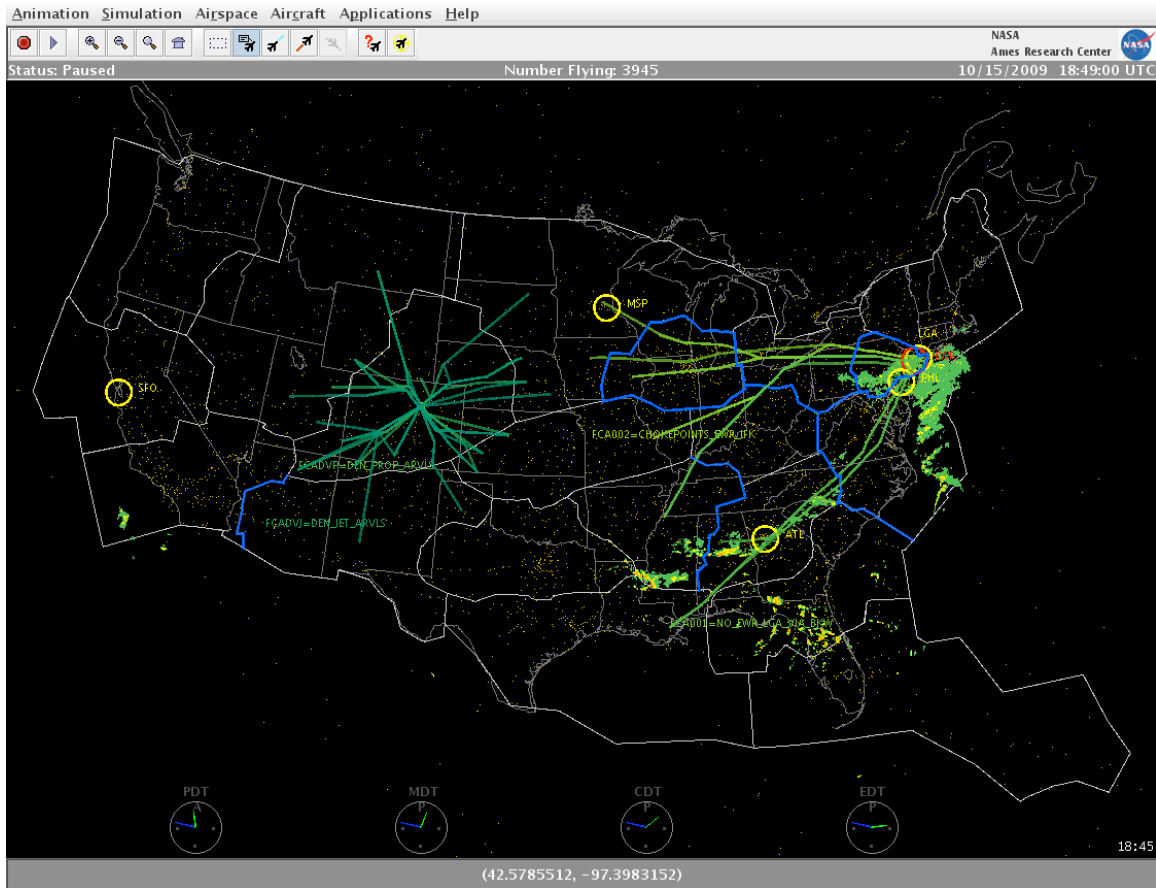


Figure 17. A frame from the TMI Viewer for data from 15 October, 2009, 18:49 UTC (2:49 P.M. EDT).

Various reroutes are denoted in shades of green in the TMI Viewer. GDPs and GSs are shown in yellow and red, respectively. An MIT restriction between two Centers is denoted by a blue border between the Centers. The current implementation simply displays this data visually. Future improvements will likely incorporate a method for “drilling” into the visual data to obtain specific data on any given TMI. For example, clicking or hovering over a GDP might provide all of the relevant parameters of the GDP. In addition, future versions might pull historical delay data from some source (e.g. OPSNET or ASPM) and display that as well. If the NTML database could be opened for access to the tool directly, then the entire TMI Viewer could be developed into a stand-alone tool (i.e., all of the steps illustrated in Figure 16 are more consolidated) for viewing past days in the NAS complete with all national-level decisions and relevant delay data.



## VI. Conclusions and Future Directions

While the NTML is extremely useful for the day-to-day operations of the NAS, there is great potential to mine the recorded data for information that could improve the decision making on Traffic Management Initiatives. The presentation of this data is a first step toward providing the FAA with a tool or set of tools which may be used to determine a potential set of TMIs given a predicted weather and traffic pattern. Future development will initially focus on the items described at the end of Section V for improving the TMI Viewer. Other important research will be to determine a method for extracting relevant days or scenarios from the NTML database for use within the TMI Viewer. For example, given a predicted traffic pattern and predicted weather phenomenon, can ten similar scenarios be easily selected from historical data to aid in making decisions in the current scenario? Also, the TMI Viewer could be used within “what-if” analysis of potential sets of TMI implementations. There are many important questions that can be formulated such that the NTML database could provide useful guidance in seeking their answers.

## Acknowledgements

This work would not have been possible without assistance from Lara Cook of Mosaic ATM who helped decipher some cryptic data and validate some of the counting methods. In addition, discussions with the TMU at ZOA proved invaluable in understanding how decisions are actually made and how data is entered and accessed. Finally, thanks to Michelle Eshow at NASA for securing access to the NTML database.

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